Reaction of Non-metals with Air (Oxygen) and Water

i. Definition

What are Non-metals? Non-metals are elements that do not have the properties of metals. They are typically brittle (break easily), not shiny, and are poor conductors of heat and electricity.

Examples: Carbon (in charcoal), Sulfur (yellow powder), Phosphorus, Oxygen, Nitrogen.

What is a Chemical Reaction?

A chemical reaction is a process where one or more substances (reactants) are changed into one or more new and different substances (products).

In this topic, we will explore how non-metals react with two very common substances: air (specifically oxygen) and water. The main idea to remember is:

Non-metals react with oxygen to form non-metallic oxides, which are generally acidic in nature.

ii. Key Points and Important Terms

- **Non-metal:** An element that lacks metallic properties (e.g., Carbon, Sulfur).
- **Oxygen:** A highly reactive non-metal gas found in the air, essential for combustion (burning).
- **Oxide:** A chemical compound that contains at least one oxygen atom.
- **Non-metallic Oxide:** A compound formed when a non-metal reacts with oxygen (e.g., Carbon Dioxide, Sulfur Dioxide).
- **Acidic Oxide:** A non-metallic oxide that, when dissolved in water, forms an acid.
- **Acid:** A substance that tastes sour (never taste chemicals!), and most importantly, turns blue litmus paper red.
- **Litmus Paper:** A special paper used as an indicator to test whether a substance is acidic or basic.
- **Acid:** Blue litmus turns Red. (Remember: Acid turns Blue Red - ABR)
- **Base:** Red litmus turns Blue.

Detailed Examples: The Two-Step Reaction

The reaction happens in two main steps:

- **Step 1:** The non-metal reacts with oxygen (from the air).
- **Step 2:** The product from Step 1 (the oxide) reacts with water.

Part A: Reaction of Non-metals with Air (Oxygen)

When non-metals are burned in the presence of air, they react with oxygen to form non-metallic oxides.

General Equation: Non-metal + Oxygen → Non-metallic Oxide

Example 1: Carbon

- **Reaction:** When charcoal (a form of carbon) is burned in air, it glows red and reacts with oxygen.
- **Word Equation:** Carbon + Oxygen → Carbon Dioxide
- **Chemical Equation:** $C + O_2 \rightarrow CO_2$
- **Observation:** A colorless, odorless gas (carbon dioxide) is produced.

Example 2: Sulfur

- **Reaction:** When sulfur powder is heated in a spoon and placed in a gas jar of air, it burns with a blue flame.
- **Word Equation:** Sulfur + Oxygen → Sulfur Dioxide
- **Chemical Equation:** $S + O_2 \rightarrow SO_2$
- **Observation:** A colorless gas with a pungent, suffocating smell (sulfur dioxide) is produced.

Part B: Reaction of Non-metallic Oxides with Water

The non-metallic oxides formed in Part A are generally acidic. We can prove this by dissolving them in water and testing the solution with litmus paper.

- **General Equation:** Non-metallic Oxide + Water → Acid

Example 1: Carbon Dioxide with Water

- **Reaction:** When carbon dioxide gas is passed through water, it dissolves to form an acid.
- **Word Equation:** Carbon Dioxide + Water → Carbonic Acid

- **Chemical Equation:** $CO_2 + H_2O \rightarrow H_2CO_3$
- **Testing the Product:** If you dip a strip of blue litmus paper into this solution, it will turn red. This proves that carbonic acid is an acid, and therefore carbon dioxide is an acidic oxide.

Example 2: Sulfur Dioxide with Water

- **Reaction:** When the sulfur dioxide gas is collected in a gas jar and water is added and shaken, the gas dissolves to form an acid.
- **Word Equation:** Sulfur Dioxide + Water → Sulfurous Acid
- **Chemical Equation:** $SO_2 + H_2O \rightarrow H_2SO_3$
- **Testing the Product:** If you dip a strip of blue litmus paper into this solution, it will turn red. This proves that sulfurous acid is an acid, and therefore sulfur dioxide is an acidic oxide.

iii. Common Misconceptions and Clarifications

Misconception	Clarification
"All non-metals react with air easily."	Not true. Some non-metals, like the noble gases (Helium, Neon), are very unreactive. Others, like carbon and sulfur, need to be heated to start the reaction.
"Air is the same as oxygen."	Not true. Air is a mixture of gases. It is about 78% nitrogen, 21% oxygen, and small amounts of other gases. The reaction we study is specifically with the oxygen in the air.
"All oxides are acidic."	Not true. This is a key difference between metals and non-metals. Non-metallic oxides are generally acidic, while metallic oxides (e.g., rust/iron oxide) are generally basic.
"Non-metals react directly with water."	Generally not true. Most non-metals (like carbon and sulfur) do not react with water under normal conditions. It is their oxides that react with water to form acids.

iv. Practice Problems with Step-by-Step Solutions

Problem 1: A student burns a piece of phosphorus (a non-metal) in a jar of air. It burns brightly to form a white solid powder called phosphorus pentoxide.

- (a) Write the word equation for this reaction.
- (b) The student then adds water to the jar and shakes it. The white powder dissolves. What type of substance is formed?

- (c) How would the student test the solution to confirm its nature? What would be the result?

Word Equation:

- **Step 1:** Identify the reactants: Phosphorus and Oxygen (from the air).
- **Step 2:** Identify the product: Phosphorus pentoxide.
- **Step 3:** Write the equation: Phosphorus + Oxygen → Phosphorus Pentoxide

Type of substance formed:

- **Step 1:** Recall the rule: Non-metallic oxide + Water → Acid.
- **Step 2:** Phosphorus pentoxide is a non-metallic oxide. When it dissolves in water, it will form an acid (specifically, phosphoric acid).

Test and Result:

- **Step 1:** Recall the test for an acid: Use blue litmus paper.
- **Step 2:** Describe the procedure: The student should dip a piece of blue litmus paper into the solution.
- **Step 3:** State the expected result: The blue litmus paper will turn red, confirming the solution is acidic.

Problem 2: Fill in the blanks: When a non-metal like sulfur reacts with _____, it forms a non-metallic oxide called _____. This oxide is _____ in nature because when it dissolves in water, it forms an _____ which turns _____ litmus paper to _____.

Solution:

- When a non-metal like sulfur reacts with oxygen, it forms a non-metallic oxide called sulfur dioxide. This oxide is acidic in nature because when it dissolves in water, it forms an acid which turns blue litmus paper to red.

v. Summary of Main Concepts

- Non-metals react with oxygen (in the air) to form non-metallic oxides.
- Non-metal + Oxygen → Non-metallic Oxide
- Non-metallic oxides are generally acidic in nature.
- We can prove they are acidic by dissolving them in water. They react with water to form acids.

- Acidic Oxide + Water → Acid
- The presence of an acid is confirmed using blue litmus paper, which turns red.
- Common examples are Carbon forming Carbon Dioxide (which makes Carbonic Acid) and Sulfur forming Sulfur Dioxide (which makes Sulfurous Acid).